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ORIGINAL CONTRIBUTION

Robert Earle Buchanan: An Unappreciated Scientist

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Robert Earle Buchanan (1883-1973), 19th President of the Society of American Bacteriologists (later American Society for Microbiology), was one of the more important 20th century microbiologists. He was a dominant force in creating the field of bacterial systematics and made significant contributions to microbial physiology. He also numbered a number of influential textbooks. A reasonable conclusion is that Buchanan was a major cultivator of modern microbiology. To justify that assertion, I have four major objectives in this essay: i) a brief biographical review of Buchanan's early life; ii) a brief review of his scientific contributions, many of which go beyond his recognized contributions to bacterial systematics; iii) Buchanan was an important academic administrator who created the microbiology program and fostered a strong graduate education program at Iowa State; iv) finally, I close the essay with a focus on Buchanan's "moral character."

INTRODUCTION

I believe it appropriate to provide the reader with a brief explanation for this essay's title. My early scientific training was in chemistry and biochemistry, and my early image of Robert Buchanan, of Iowa State, was shaped primarily by his role as Editor of *Bergey's Manual of Determinative Bacteriology*. The biochemist in me found arguments over bacterial taxonomy, as my students say today, *BORING*!! My image of Buchanan was of a man wearing an accountant's green eyeshade, counting up the number of characteristics necessary to decide if one strain of *Pseudomonas* was sufficiently different from another that it should be considered a separate species.

I have slowly realized the importance of bacterial systematics to microbiology as a science and have also grown to recognize Buchanan's central role in that area. Of greater importance, however, I have also grown to realize that Buchanan was a much broader scientist than suggested by his role in systematics. Indeed, I have concluded that Buchanan was a major cultivator of modern microbiology, and the rationale for

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[b] *Abbreviations:* SAB, Society of American Bacteriologists; ASM, American Society for Microbiolog
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Figure 1. Photograph, taken by Pammel, of Buchanan as an undergraduate student. (Source Iowa State Univ. Library/Univ. Archives)

this conclusion is a major goal I have for this essay.

To this end, I have four major objectives in the essay. First, I will briefly review some early biographical dimensions of Buchanan's life. Based on that biographical sketch, I will discuss three broad aspects of Buchanan's character. As implied by the title, a major dimension of this discussion will be on his scientific contributions, many of which go beyond his recognized contributions to bacterial systematics. Buchanan was also an important academic administrator who created the microbiology program and fostered a strong graduate education program at Iowa State. Finally, in closing, I will focus on what I call Buchanan's "moral character," for want of a better phrase. While I present these as separate goals, obviously they are all closely related.

BIOGRAPHICAL BACKGROUND

Robert Earle Buchanan (1883-1973) was born March 27, 1883, in Cedar Rapids, Iowa. Except for a year, when he was nine, he lived all of his early years in the frontier town of Eagle Grove. Buchanan commented that while the frontier nature of the town made the hickory cane an inducement to learning, "excellent instruction was available to those who wanted it." In high school, he developed a lasting interest in mathematics, which was reflected in much of his later work as well as his belief that biology students should complete mathematics at least through calculus.

Buchanan also cultivated an interest in botany in high school, and he developed a herbarium, skills that later played an important role in his life. That botanical interest was fostered when Buchanan entered

[c] All dates are from the ASM Archives website: http://www.asmusa.org/mbrsrc/archive/part13.htm, "Part 13: Presidents, Section II. Presidents."

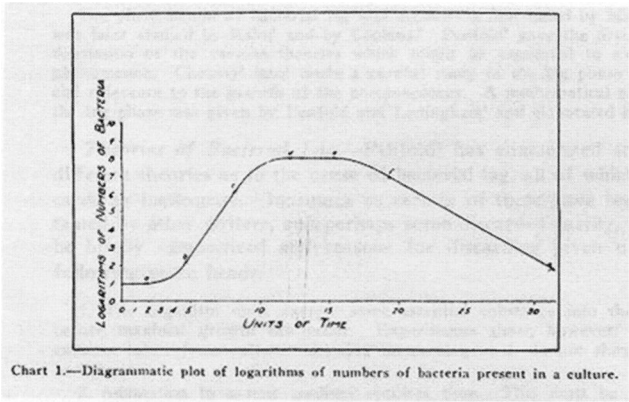

Chart 1.—Diagrammatic plot of logarithms of numbers of bacteria present in a culture.

Figure 2. Figure 1 from Buchanan, R.E. "Life Phases in a Bacterial Culture," *J. Infect. Dis.* 23:109-25, 1918. (©University of Chicago Press, with permission.)

Iowa State College in the fall of 1900 and immediately sought out contact with Louis H. Pammel, professor of botany and a charter member of the newly formed Society of American Bacteriologists (SAB)[b], later to become the ASM.

The two men formed a strong mentoring relationship, and Buchanan has noted that Pammel "practically adopted" him. As an undergraduate, Buchanan worked with Pammel as a student assistant. The interaction appears to have begun as a strong mentor-student relationship that rapidly evolved to one of close scientific colleagues as well as personal friendship. The relationship is reflected in this casual photograph of Buchanan as a student in 1903 taken by Louis Pammel (Figure 1). Buchanan accompanied Pammel on botanical surveys and did extensive work in the college herbarium. The current Iowa State herbarium includes material that Buchanan helped assemble.

During the summer after his 1904 Iowa State graduation, Buchanan pursued two interesting activities. Part of the summer was spent in the sand hills of Nebraska identifying and collecting grasses. He spent the rest of the summer at Northwestern University medical school to, as he said, "learn the lingo" for a fall teaching assignment at Iowa State in veterinary bacteriology. He returned to Ames in the fall of 1904 and continued working with Pammel as a bacteriology teaching assistant and completed an M.S. in 1906.

In a 1959 letter to Paul Clark [1], Buchanan states that he was on "leave of absence from I.S.C." at the University of Chicago during the years of 1907-1908. During that two-year period, he taught bacteriology for medical and home economics students, as well as a graduate course in soil bacteriology. In the summer of 1908, he completed his Ph.D. thesis with E.O. Jordan on nodule bacteria of legumes and returned to Iowa State as an associate professor.

Buchanan's career was on what some people today might refer to as a "fast track," but I suspect his career was not all than unusual for his contemporaries. Nevertheless, consider that within a span of four years he progressed from undergraduate teaching assistant to associate professor at Iowa State. Furthermore, within a decade (1918) he was elected president of the SAB.

At age 35, Buchanan was the youngest person to serve as SAB/ASM president, however youth did not appear to be an obstacle to Society office in the early years. For example, Charles-Edward A. Winslow (1877-1957), who served five years prior to Buchanan (1913) was 36, Edwin O. Jordan (1866-1936) — elected in 1905 — was 39, and Frederick G. Novy (1864-1957), SAB president in 1904, was only 40. This observation appears to be part of a clear trend. Statistical analysis of the age and year of presidential election of the 100 persons who have served as SAB/ASM president shows the average age has increased about 10 years during the century[d].

BUCHANAN AS SCIENTIST

Many people recognize Buchanan for his contributions to bacterial systematics, which were significant. For example, the first edition of Cowan's *Dictionary of Microbial Taxonomic Usage* is dedicated "to R.E. Buchanan, The Father of Bacterial Nomenclature" [2]. While Buchanan's commitment to bacterial nomenclature was almost legendary, his contributions to microbiology were much broader. Cowan summarized this point in his Buchanan obituary when he stated "Buchanan was a microbiologist extraordinary" [3].

A detailed discussion of Buchanan's bacterial taxonomy work here is difficult. First, the work was so large and complex, adequate discussion would require a separate essay. His correspondence on the topic in the Iowa State University Archives alone is voluminous. Furthermore, by focusing on his role in bacterial systematics it becomes easy to overlook his significant contributions that helped shape modern microbiology as a discipline. Indeed, I suspect that few working microbiologists are aware of Bufchanan's contributions to microbiology's disciplinary structure.

Consider, for example, the figure from his 1918 paper on bacterial growth [4], which has been reproduced in one form or another in every microbiology textbook since then (Figure 2). In this paper, Buchanan established the fundamental differential equations to describe bacterial growth. Other workers, such as William Mansfield Clark, were beginning to describe bacterial growth using exponential notation, but as far as I can determine, Buchanan was the first person to actually do this in a systematic and formal way. The concept is so simple as to seem trivial. Yet the nature of bacterial growth is fundamental to microbial physiology and is what the philosopher of science, Philip Kitcher [5], might call a consensus practice that helps to define microbiology as a discipline.

As his bacterial growth paper illustrates, Buchanan brought mathematical rigor to the developing discipline of microbiology. When he helped create the new bacteriology department at Iowa State (see below), he instituted a calculus requirement for the undergraduate degree. He also enjoyed mathematics, and his skills were perhaps better than many of his contemporary bacteriologists. For example, he casually scribbled a complex series of differential equations on the back of a form letter from American Express with travel arrangements for the 1932 Inter-national Congress of Microbiology. The equations described how one could follow bacterial growth by measuring lactic acid

[d] Singleton, R. , Jr. Unpublished analysis. All data were from the ASM Archives (see footnote c). Presidential age, calculated from the years of birth and death (1999 in the case of individuals still alive) and year of presidential term were entered into a spreadsheet (Quarto QPro©) database. The data were then fitted to a linear regression line using the software's statistical functions.

production as a growth product. The notes have the appearance of a casual attempt to explain a phenomenon to a colleague, and Buchanan simply reached for the closest piece of paper available [6].

Perhaps Buchanan's major scientific contribution, in addition to his contributions to microbial physiology and bacterial systematics, was introducing the rigor of mathematics, physics, and especially chemistry to microbiology through a series of influential textbooks. For example, *Agricultural and Industrial Bacteriology* [7], initially published in 1921, underwent several editions and was widely used. The three-volume treatise, *Biochemistry and Physiology of Micro-organisms* [8-10], written by Buchanan and Ellias Fulmer was extremely influential. I suspect that the first volume of this series, published in 1928 [8], influenced Harland Wood to pursue graduate work at Iowa State [11, 12].

The Buchanan-Fulmer monograph achieved international distinction for Buchanan personally and for Iowa State as an institution. When the distinguished Dutch microbiologist/biochemist A.J. Kluyver was a visiting professor at Iowa State during the spring and summer of 1932 [13], he commented that "... there will be but a few students of general microbiology in Europe who will not often consult the standard treatise on the physiology and biochemistry of bacteria by Dean Buchanan and Professor Fulmer [14]."

Kluyver also apparently had a deep personal appreciation for Buchanan's contributions to microbiology. During his travels he carried a number of small notebooks in which he recorded various daily activities. One book contains the notation, "Leeuwenhoek portrait Presented to Dr. R. E. Buchanan who so greatly promoted the dissemination of Leeuwenhoek's science in America, (signed AJK) May 1932." There are other notations of presenting similar portraits, but none contain the extensive personal autograph [15].

Buchanan reciprocated the appreciation and was deeply influenced by Kluyver's work. For example, the third volume of Buchanan and Fulmer's bacterial physiology opened with an aphorism from Kluyver and Donker's *Die Einheit in der Biochemie.* Despite his great admiration for Kluyver, Buchanan was not afraid to challenge Kluyver's ideas when he thought them misguided. For example, during his stay in Ames, Kluyver ran a biweekly "Microbial Physiology" seminar. One of these evenings was a "trialogue" debate on "The Significance to be Attributed to the Term Fermentation" and involved presentations by Kluyver, Chester Werkman, and Buchanan [13].

In his presentation, Kluyver developed and defended a traditional Pasteurian definition of fermentation. He noted that much confusion developed about the term, but that if it was to retain any semblance of meaning, there must be some return to Pasteur's original concept of "metabolic processes proceeding without the cooperation of free oxygen" [16].

In his response, Buchanan was deferential to Kluyver's position both as a distinguished scientist and as a guest. Nevertheless, he forcefully challenged many of Kluyver's views. A notation on his typed text, in Kluyver's papers at Delft, reads, "Respectfully submitted to Dr. A.J. Kluyver, with the hope that it be suitably expurgated, corrected, and emended, and in the end lead to a clarified vision on the part of the present writer" [17]. Buchanan then proceeded to critically analyze and dissect Kluyver's argument. Kluyver quoted sentences from Pasteur; Buchanan quoted entire paragraphs. Seemingly, Buchanan's goal was not to demonstrate Kluyver's inadequacy but rather to illustrate numerous alternative understandings of the term "fermentation." After a devastating critique of "the present status of French bacteriology"

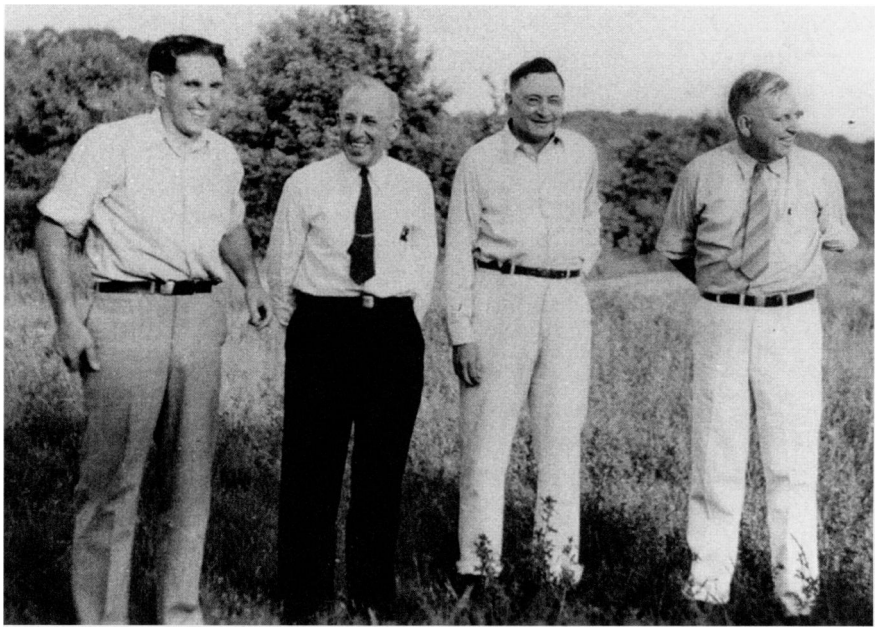

Figure 3. Iowa State bacteriology core faculty and graduate student Harland Wood, ca. early 1930s. From right to left: Wood, Levine, Werkman, and Buchanan. (Photo courtesy of Robert Werkman.)

and the Pasteur Institute, which are concerned with "too much retrospection, too much hero worship," Buchanan suggested "several possible definitions of fermentation based on the American concept." He then outlined a series of possible understandings of the term "fermentation," many of which verge on our modern understanding.

BUCHANAN AS ADMINISTRATOR

I hope this précis of Buchanan's scientific work provides a rationale for believing that he significantly helped create the modern discipline of microbiology. Buchanan also contributed to that disciplinary shaping through his role as an academic administrator. His obituary writer, S. T. Cowan, considered Buchanan's administrative abilities to be one of his strongest influences on the field of microbiology.

To place Buchanan's administrative abilities into context, I must briefly recapitulate some of the early history of bacteriology at Iowa State. In 1910, Pammel recommended that bacteriology be taught as a separate discipline from botany and that Buchanan should head the new department. A few years later, in 1913, Buchanan believed the department needed a sanitary bacteriologist, and in his letter to Paul Clark said, "So we took up the matter with Dr. Sedgwick of the Massachusetts Institute of Technology who recommended his star pupil, Max Levine, who came to us to teach and to carry on research in this field" [1].

Max Levine (1889-1967) completed a B.S. in sanitary bacteriology at MIT with W.T. Sedgwick in 1912, joined the Iowa State faculty as an instructor in 1913, and was promoted to assistant professor 1914. Two years after completing a Ph.D. at the

Figure 4. Photograph of "Dean Buchanan" illustrates one of the many administrative hats he wore in 1925. (Source: Iowa State University Library/University Archives.)

University of Iowa in 1922, Levine was promoted to full professor.

Buchanan's comment that "Levine . . . came to us to teach and to carry on research . . . " seems almost insouciant, for Levine rapidly became one of the country's leading water quality/sanitary microbiologists. Levine's bacteriology practice was both pragmatic and conceptual. Papers from his laboratory revolved around practical problems, such as increasing the efficiency of bottle cleaning, to more fundamental problems associated with isolation and characterization of bacteria involved in disease processes.

Levine also played an important administrative role at Iowa State. As Buchanan began to assume various higher level administrative functions in the early 1930s, Levine was designated "Professor in Charge of Department." The historical record, while vague regarding the duties of this ambiguous title, implies that Levine was the *de facto* department head. His appointment as "Professor in Charge" was distinguished from other salary lines in the annual budget, and he signed graduate theses in the space normally designated for the department head. Levine designated himself as "Professor in Charge of Department" in biographical publications such as *American Men of Science* and *Who's Who in America*. He retained the title until 1945 when he was replaced by Chester Werkman upon Buchanan's forced retirement [13].

Chester Werkman (1893-1962), Buchanan's former graduate student, joined this developing bacteriology department in the mid-1920s. After completing a

B.S. in chemistry at Purdue, Werkman completed the Ph.D. at Iowa State with Buchanan in 1923. After a year as an assistant professor at the University of Massachusetts, he returned to Iowa State as assistant professor of bacteriology. He was promoted to associate professor in 1927 and full professor in 1933. Like Levine, Werkman developed a national and international reputation; unlike Levine, Werkman's career was built on his biochemical contributions rather than his bacteriological work [13].

Initially Werkman's research focus was a continuation of his graduate research, however, in response to an Iowa State agricultural initiative, he began a program to study bacterial fermentations. Influenced by European biochemists, such as A.J. Kluyver, who visited Ames in 1932, Werkman began a microbial physiology research program deeply rooted in biochemistry. Aided by a coterie of talented graduate students, such as Harland Wood, Mert Utter, Less Krampitz, David Paretsky, George Kalnitsky, and Russell Brown — to name a few — Werkman's laboratory became a leading national and international biochemical center to study microbial metabolism.

Thus, by the 1930s, Buchanan had established one of the foremost bacteriology programs in the country that attracted first-rate graduate students who made significant scientific contributions. Harland Wood (Figure 3), for example, described the process of heterotrophic CO_2-fixation, commonly referred to as the "Wood-Werkman Reaction," as part of his graduate work. Over the next decade, Wood, Werkman, and their collaborators co-authored more than forty papers that fleshed out the biochemical details of this process. Wood eventually moved to chair the biochemistry department at Western Reserve University and helped build it into one of the most prestigious biochemistry programs in the country. Wood, Mert Utter, Less Krampitz, and their mentor Werkman, were all elected to the National Academy of Sciences [11, 12].

While there were other bacteriology programs at Iowa State, such as dairy and veterinary bacteriology, Buchanan, Levine, and Werkman constituted the core bacteriology department. The department taught the general bacteriology curriculum and trained graduate students. As Margaret Rossiter observed, Iowa State had "the largest graduate enrollment of any of the separate land grant colleges" in the late 1920s [18], thus graduate training was a major enterprise.

Buchanan's administrative involvement at Iowa State went far beyond the departmental level. Indeed, his involvement was complex and often appears to have been almost labyrinthine. For example, Buchanan was Head of the bacteriology department from its inception in 1910 until 1945[e]. Simultaneously he also served as Dean of Industrial Science from 1914-1916, Dean of the Graduate College from 1919-1945, and Director of the Agricultural Experimental Station from 1933-1945. In addition to these "local" positions, Buchanan played several national and international roles, such as the 19th SAB

[e] Department leaders were referred to by various titles at Iowa State. Chemistry had a "Chair," whereas mathematics had a "Head." Furthermore, titles designating departmental leaders changed over the years, perhaps as a department changed its name or mission. ("Archival Index, Iowa State University," Iowa State University Archives, Ames, Iowa, Record Group 13/15.) For many years, the Bacteriology Department was led by a "Head," whereas leaders of the Microbiology Department, after a name change, were referred to as "Chairs." Paul Hartman, a former department Chair, made the distinction that a department "Head" was "much more difficult to 'dispose of' than a departmental chair." (P. A. Hartman, Letter to author [April 24, 1995]).

President, editor of numerous editions of *Bergey's Manual* and various journals, and member of the National Research Council.

This complexity of administrative roles leads me to my last goal, Buchanan's "moral character." In at least one administrative activity, Buchanan demonstrated, what for me, was extraordinary moral principle and commitment.

BUCHANAN'S MORAL CHARACTER

Several years ago, while working with Buchanan's papers at Iowa State, I found a file folder labeled, in Buchanan's hand, "Werkman-Levine Controversy." The folder contained correspondence between Buchanan, Iowa State University President Charles Friley, Max Levine, and others. The story the folder tells is complex and has important insights into ways that disciplines and departments evolve and change. The story also illustrates Buchanan's capacity for "speaking the truth" as he perceived it. It is hard to imagine a modern faculty member writing to a university president in such direct and personal language.

In 1941, Max Levine was in military service, and in his absence Werkman served as "Professor in Charge." However, Werkman's national and international prestige were flourishing, thus administrative maneuvering began to move Buchanan out and make Werkman permanent department head. The Friley-Buchanan correspondence implies that Werkman would be in a better position to lead the department in the post-war years, because his biochemical research was perceived as "more modern."

In July 1945, Buchanan was forced into retirement, and Werkman formally appointed head of the bacteriology department. From Buchanan's perspective, the appointment was contentious for at least two reasons. Buchanan believed that Levine was entitled to the position and believed that the administration was obligated to defer any action until Levine returned from military service. In his correspondence to President Friley, Buchanan did not mince words; the institution had a legal obligation not to abolish Levine's position while he was in the military, even if it did not recognize that moral obligation. Responding to a letter from President Friley, Buchanan unequivocally stated his position:

> You state that no injustice has been done Colonel Levine by your abolishing the position which he occupied when he was called as a reserve officer into the service. I cannot but reiterate my complete disagreement with your position. Further, the action is impolitic as it quite possibly may give rise to criticism of the relationship of the institution to returning veterans. You argue that the title "professor in charge" is an annual appointment. But so is the title of instructor. You may be able to defend yourself from attack, but you have definitely maneuvered yourself into a defensive and weak position. [19]

Buchanan also lacked confidence in Werkman's leadership ability and the direction in which he believed Werkman would lead the department. Again, Buchanan's opinion was blunt; [Werkman] "had not shown the qualities of administrative ability and teaching leadership that would justify appointment as head of as important a teaching and research department as Bacteriology" [19]. Buchanan was also foresightful; the department did not prosper under Werkman's administration [13]. The decline was fostered by many factors, which are beyond the scope of this essay. Drastic differences in Werkman's leadership style, in comparison with his predecessors, were perhaps the most significant cause of the department's eclipse. According to former department members, Werkman was petty and autocratic as department head; these

traits created dissension or discord and led to a loss of spirit in the department. Younger faculty members left for positions elsewhere, as did members of Werkman's own laboratory. Personally Werkman could no longer sustain the successful laboratory operation of the previous decades, and consequently the biochemical strength that Werkman brought to the bacteriology department was dissipated.

In about a decade, Werkman retired because of ill health and died a few years later. "Dean" Buchanan, however, continued on. After retirement he maintained an office on campus and remained active in university affairs. He continued to play on the scientific stage in both national and international venues. He had the distinction of attending every International Congress of Microbiology [3] and continued as editor of the *International Journal of Systematic Bacteriology*. He was actively editing the eighth edition of *Bergey's Manual of Determinative Bacteriology* shortly before his death in 1973 [20].

CONCLUSION

A major goal of this symposium was to understand the lives of the individuals who provided SAB and ASM leadership. I have touched very little on the role that Buchanan played in society affairs but rather sought a wider understanding of his life. I have tried to address the broader question of "Why was Buchanan of such significance that the society elected him to leadership?" I am not certain that I have fully answered that question, but a final European perspective of Buchanan may provide that insight.

After Buchanan's death, the *Journal of General Microbiology* published an extensive obituary [3][f]. I recently asked John Postgate, who was then the journal's Editor, why the British Society for General Microbiology wrote such a significant obituary on Buchanan, an American microbiologist. His response was as follows:

> My recollection of the situation in the later 1940s, when I was a neophyte microbiologist, is that Buchanan's reputation extended beyond bacterial systematics into their growth, culturing and diagnostics; only in later years did taxonomy and systematics overshadow the rest. But his lasting fame came with the latter and Cowan's obit would have reflected that.
>
> The Journal's policy on obituaries was to restrict them to very distinguished members of the Society whatever their speciality. Distinction, not subject area or nationality, was what mattered — They were all General Microbiology.
>
> How measure distinction? Not easy. But usually consensus prevailed. In the case of Buchanan, no-one would have had doubts — in Europe he was seen to be a father figure of general bacteriology[g].

Losing sight of our disciplinary roots is easy. Microbiology, even microbial systematics, changed greatly during Buchanan's life, as biochemistry and molecular biology began to play an important disciplinary role. By introducing the rigor of mathematics, chemistry, and physics into bacteriology, Buchanan helped foster those changes. For many microbiologists engaged in active research, historical reflection consists of digging out an old journal from last year. That historical myopia, however, causes us to lose sight of the giants who built our discipline. R.E. Buchanan, as scientist, administrator, and moral compass, was one of the giants upon whose shoulders every modern microbiologist stands.

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[f] Although the obituary's author was identified only by the initials "S.T.C.," Samuel T. Cowan, a member of the Editorial Board was the author.
[g] Postgate, J. E-mail correspondence to the author, May 5, 1999.

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